

CHAPTER 5 DOCUMENTING TECHNOLOGY PERFORMANCE

5-1. General. This chapter provides additional information on documenting technology performance in the RA report, expanding on concepts presented in the previous chapter (Paragraph 4-6). Technology performance should be documented in Section 5 and Appendix A of the RA report.

5-2. Recommended Performance Reporting.

a. The performance of a technology is often characterized only in terms of the percentage of contaminants removed or the concentration of contaminants remediated. However, that information alone will not adequately assess all aspects of a technology's performance. For example, this one-dimensional measure of performance will not document any of the problems that might have arisen during the technology's application, or how such problems were resolved. The information listed in Exhibit 5-1 should be included in the RA report so that the effectiveness and the appropriateness of the remedy can be quantified and compared with other alternatives when making future remedy selections at other sites with similar characteristics.

b. Exhibit 5-1 provides a guide to ensure that all important information related to the performance of the technology will be documented in the RA report. The level of detail and data available for each performance topic will vary by technology type and the specific application.

Exhibit 5-1 Recommended Performance Reporting

Performance Topic	Type of Information
Types of samples collected	<ul style="list-style-type: none"> ◆ Types of media sampled ◆ Types of constituents analyzed ◆ Use of surrogates (e.g., soil gas as a surrogate for soil borings)
Sample frequency and protocol	<ul style="list-style-type: none"> ◆ Where samples were collected ◆ How samples were collected ◆ When samples were collected ◆ Who collected samples
Quantity of material treated	<ul style="list-style-type: none"> ◆ Quantity of material treated during application ◆ For in situ technologies, area and depth of contaminated material treated
Concentrations of untreated and treated contaminants (range and median values)	<ul style="list-style-type: none"> ◆ Measurement of initial conditions (even if not required to demonstrate compliance with cleanup/remediation criteria) ◆ Measurement of concentrations of contaminants during or after treatment (note whether data exists for both treated and untreated contaminants or whether operating data exists that corresponds with performance data) ◆ Assessment of percent removal achieved (note procedure used to derive percent removal) ◆ Correlation of performance data with other variables

Exhibit 5-1, cont.

Recommended Performance Reporting

Performance Topic	Type of Information
Cleanup goals and/or remediation objectives	<ul style="list-style-type: none"> ◆ Cleanup goals and/or remediation objectives and source(s) ◆ Criteria for ceasing operation
Comparison with cleanup goals/remediation objectives	<ul style="list-style-type: none"> ◆ Assessment of whether the technology achieved the cleanup goals/remediation objectives ◆ Assessment of whether the technology achieved reductions in concentrations of contaminants beyond the established cleanup goals/remediation objectives
Method of analysis	<ul style="list-style-type: none"> ◆ Methods of analysis used (including field screening and/or analyses, portable instruments, mobile laboratory, off-site laboratory, laboratory procedures, analytical methods, explanation of any nonstandard methods) ◆ Exceptions to standard methodologies
Quality assurance and quality control (QA/QC)*	<ul style="list-style-type: none"> ◆ Person responsible for QA/QC ◆ Type of QA/QC measures performed ◆ Level of procedures ◆ Exceptions to QA/QC protocol or data quality objectives
Other residues	<ul style="list-style-type: none"> ◆ Types of residues generated (e.g., off-gases, wastewaters, or sludges) ◆ Measurement of mass or volume, and concentration of contaminants in each treatment residue
* Note that only general QA/QC information is recommended; any exceptions to the QA/QC procedures should be documented.	

c. For RA reports involving long-term response actions, such as groundwater pump and treat remedies, interim RA reports should include the most recent performance results, and information about the project's progress and status in order to indicate how well a technology has been performing over time. Final RA reports should update the performance data included in the interim report once the project has been completed.

5-3. Factors that Affect Cost and Performance.

a. The *Guide to Documenting and Managing Cost and Performance Information for Remediation Projects* (EPA 542-B-98-007) lists factors that can affect the cost or performance of a treatment technology and recommends that those factors be documented when reporting technology cost and performance. These include matrix characteristics, such as soil types, soil properties, and organic contaminants that may be present in a matrix being treated; and operating parameters of the treatment system, such as residence time and system throughput. Nonmatrix characteristics such as geology and hydrogeology for in situ applications are also important to document. Technologies for which factors are provided are listed in Exhibit 5-2. Suggested parameters to report for these technologies are provided in Exhibit 5-3.

Exhibit 5-2 Example Remedial Technologies

<p style="text-align: center;">Ex Situ Soil Remediation</p> <ul style="list-style-type: none"> ◆ Composting ◆ Incineration ◆ Land Treatment ◆ Slurry-Phase Bioremediation ◆ Soil Washing ◆ Stabilization ◆ Thermal Desorption 	<p style="text-align: center;">Groundwater Remediation and/or Containment</p> <ul style="list-style-type: none"> ◆ Air Sparging ◆ Bioremediation ◆ Bioslurping ◆ Circulating Wells (UVB) ◆ Cosolvents and Surfactants ◆ Multi-Phase Extraction ◆ Dynamic Underground Stripping ◆ In Situ Oxidation (Fenton's Reagent) ◆ Natural Attenuation (Chlorinated Compounds) ◆ Natural Attenuation (Nonchlorinated Hydrocarbons) ◆ Permeable Reactive Barriers ◆ Phytoremediation ◆ Pump and Treat System ◆ Steam Flushing ◆ Vertical Barrier Walls
<p style="text-align: center;">In Situ Soil Remediation and/or Containment</p> <ul style="list-style-type: none"> ◆ Bioventing ◆ Capping ◆ In Situ Heating ◆ Phytoremediation ◆ Soil Flushing ◆ Soil Vapor Extraction ◆ Vitrification 	

b. For the RA report, both matrix characteristics and operating parameters of the treatment system should be reported in an appendix as well as site conditions (e.g., geology/hydrogeology), as applicable, that may impact the cost and performance of the treatment technologies used in the remedy. The appendix should report the values or results of each parameter as well as the procedures used to measure the parameter.

Exhibit 5-3
Suggested Parameters to Report that Affect Cost and Performance

Technology		Operating Parameters		Soil Types		Aggregate Soil Matrix Properties						Organic Properties			System Parameters							Biological Activity						Misc.	
		Soil Classification	Clay Content and/or Particle Size Distribution	Hydraulic Conductivity	Moisture Content	Air Permeability	pH	Porosity	Depth or Thickness of Zone of Interest	Total Organic Carbon	Oil and Grease or Total Petroleum Hydrocarbons	Presence of NAPLs	Air Flow Rate	Mixing Rate / Frequency	Operating Pressure / Vacuum	pH	Pumping Rate	Residence Time	System Throughput	Temperature	Components/Additives & Dosage for Wash/Flush	Biomass Concentration	Microbial Activity	Oxygen Uptake Rate	Carbon Dioxide Evolution	Biodegradation Rate for Organics	Nutrients and Other Soil Amendments	Miscellaneous	
In Situ Soil Remediation and/or Containment	Bioventing	•	•		•	•	•	•	•	•		•		•						•				•	•	•	•		
	Capping	•	•	•	•										•					•								1	
	In Situ Heating	•	•		•	•		•	•	•		•		•	•					•								2	
	Phytoremediation	•	•		•			•				•		•						•						•		3	
	Soil Flushing	•	•	•				•		•		•		•		•		•											
	Soil Vapor Extraction	•	•		•	•		•	•	•		•					•												
	Vitrification	•	•		•	•														•								4	
Ex Situ Soil Remediation	Composting	•	•		•		•					•			•		•	•	•				•		•	•		5	
	Incineration	•	•		•					•							•		•	•								6	
	Land Treatment	•	•		•		•		•			•		•			•		•	•					•	•		7	
	Slurry-Phase Bioremediation	•	•		•		•		•			•		•			•		•	•		•			•	•		8	
	Soil Washing	•	•							•		•		•		•		•	•	•								9	
	Stabilization	•	•		•		•		•			•						•	•	•								10	
	Thermal Desorption	•	•		•						•						•	•	•	•								11	
Nonmatrix Characteristics that Affect Cost or Performances															Notes														
Contaminants: Type and concentration of contaminants. Cleanup goals/remediation objectives and requirements: Maximum contaminant levels, schedules, sampling and analysis. Environmental Setting (for In Situ Technologies): Geology, stratigraphy, and hydrogeology (primarily). Quantity of material treated. Cubic yards or 1,000 gallons of water.															1 Future use; precipitation; design infiltration rate; permeability of clay liner, geomembrane, or other polymer layers 2 Electrical conductivity (for electrical heating); electrical or radio frequency (RF) power input 3 Plants per unit area and plant type 4 Lower explosive limit; glass-forming metals; electrical conductivity; power consumption per unit volume; presence of inclusions 5 Moisture content; soil loading rate 6 BTU value; halogen content; metal content 7 Field capacity; moisture content 8 Density of slurry; volume fraction of water 9 Cation exchange capacity of soils 10 Curing time; compressive strength; volume increase; permeability 11 Bulk density														

Exhibit 5-3, cont.

Suggested Parameters to Report that Affect Cost and Performance

Technology		Operating Parameters		Soil Types		Aggregate Soil Matrix Properties						Organic Properties			System Parameters								Biological Activity						Misc.						
		Soil Classification	Clay Content and/or Particle Size Distribution	Hydraulic Conductivity	Moisture Content	Air Permeability	pH	Porosity	Depth or Thickness of Zone of Interest	Total Organic Carbon	Oil and Grease or Total Petroleum Hydrocarbons	Presence of NAPLs	Air Flow Rate	Mixing Rate / Frequency	Operating Pressure / Vacuum	pH	Pumping Rate	Residence Time	System Throughput	Temperature	Components/Additives & Dosage for Wash/Flush	Biomass Concentration	Microbial Activity	Oxygen Uptake Rate	Carbon Dioxide Evolution	Biodegradation Rate for Organics	Nutrients and Other Soil Amendments	Miscellaneous							
Groundwater Remediation and/or Containment	Air Sparging	●	●	●		●		●		●	●	●	●		●						●	●													
	Bioremediation	●	●	●		●		●	●	●	●	●	●	●		●					●	●	●	●	●	●	●								
	Bioslurping	●	●	●	●	●	●	●	●	●	●	●	●	●		●							●	●	●	●	●								
	Circulating Wells (UVB)	●	●	●		●		●				●	●		●		●										●								
	Cosolvents/Surfactants	●	●	●		●		●		●	●	●	●		●		●	●			●							● ¹²							
	Dual-Phase Extraction	●	●	●		●		●		●	●	●	●	●	●		●																		
	Dynamic Underground Stripping	●	●	●		●		●				●	●		●		●			●															
	In Situ Oxidation (Fenton's Reagent)	●	●	●		●			●						●	●					●		●					● ¹³							
	Natural Attenuation (Chlorinated)	●	●	●				●		●		●			●					●			●		●	●	●	● ¹⁴							
	Natural Attenuation (Nonchlorinated)	●	●	●				●		●	●	●			●					●			●	●	●	●	●	● ¹⁵							
	Permeable Reactive Barriers	●	●	●				●	●	●	●		●		●													● ¹⁶							
	Phytoremediation	●	●	●				●		●		●			●					●							●	● ¹⁷							
	Pump and Treat System	●	●	●								●			●	●												● ¹⁸							
Steam Flushing	●	●	●		●					●	●				●				●																
Vertical Barrier Walls	●	●	●		●			●	●																		● ¹⁹								
Nonmatrix Characteristics that Affect Cost or Performances													Notes																						
Contaminants: Type and concentration of contaminants.													¹² Efficiency of recovery and recycling																						
Cleanup goals/remediation objectives and requirements: Maximum contaminant levels, schedules, sampling and analysis.													¹³ Injection rates; costs of chemicals																						
Environmental Setting (for In Situ Technologies): Geology, stratigraphy, and hydrogeology (primarily).													¹⁴ Redox conditions; electron acceptors (oxygen, nitrate, iron, sulfate, methane); electron donors (e.g., carbon, presence of toluene) presence of breakdown products; levels of ethene, ethane, or methane																						
Quantity of material treated. Cubic yards or 1,000 gallons of water.													¹⁵ Dissolved oxygen levels; electron acceptors (oxygen, nitrate, iron, sulfate, methane)																						
													¹⁶ Flow rate through gate (for funnel-and-gate system); type of reactant (e.g., iron granules)																						
													¹⁷ Plants per unit area and plant type																						
													¹⁸ For the treatment component of the pump and treat system, the operating parameters will vary by the specific type of treatment used (e.g., carbon adsorption, air stripper); for additional information, please refer to <i>Technical Requirements to Report HTRW Environmental Restoration Cost and Performance</i> , USACE 1996																						
													¹⁹ Permeability of wall material and depth of key																						

c. Exhibits 5-4 and 5-5 provide examples of how matrix characteristics and operating parameters may be reported in Appendix A of the RA report for a remedial action that uses a land treatment system to remediate contaminated soil.

Exhibit 5-4 **Example Matrix Characteristics**

Parameter	Value/Result	Measurement Procedure
<i>Soil Types</i>		
Soil classification	Mixture of lagoon contents; lagoon had a clay bottom and sandy contents, which ranged from silty clay to fine sand	Because the medium treated was a mixture of lagoon contents, it did not lend itself to a formal classification analysis.
<i>Aggregate Soil Properties</i>		
pH	6.9	The value listed represents an average measured during one of the sampling events; EPA Method SW-846/9045 was used to measure the pH of the soil.
Total organic carbon	16,000 mg/kg	The value listed represents an average measured during one of the sampling events; EPA Method SW-846/9060 was used to measure the total organic carbon in the soil.
Quantity of soil treated	8,100 yd ³ (total for 3 lifts)	NA
NA - not applicable. Measurement procedures are reported only for those parameters where different procedures are available.		

Exhibit 5-5

Example Operating Parameters

Parameter	Value/Result	Measurement Procedure
System Parameters		
Soil mixing rate / frequency	Soil placed in the subplots was tilled every two weeks.	Mixing rate or frequency is the rate of tilling for land treatment.
Soil moisture content (%)	12.4 - 22.8 (Lift 1) 12.9 - 21.1 (Lift 2) 8.5 - 14.7 (Lift 3)	Soil moisture was measured using the gravimetric ASTM standard D 2216-90, <i>Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock</i> .
pH	6.6 - 7.2 (Lift 1) 6.8 - 7.5 (Lift 2) 6.4 - 7.0 (Lift 3)	Values shown represent the ranges of pH for each lift. EPA Method SW-846/9045 was used to measure the pH content.
Residence time (months)	9 - 15 (Lift 1) 6 - 10 (Lift 2) 4 (Lift 3)	Ranges are given for each lift because of the variations by subplot.
Soil temperature (°F)	13 - 99 (Lift 1) 13 - 102 (Lift 2) 29 - 102 (Lift 3)	NA
Biological Activity		
Carbon/Total Kjeldahl Nitrogen	8.8 - 15.4 (Lift 1) 8.8 - 78 (Lift 2) 6 - 67 (Lift 3)	Values represent the ratio of Carbon to Total Kjeldahl Nitrogen in the soil at the time of measurement for each lift. Ranges are shown for the eight treatment subplots. EPA Methods 415.1 (Modified) and 351.1 (Modified) were used.
Hydrocarbon degradation (mg/kg/month)	13 - 58 (Lift 1) No values were determined for Lifts 2 and 3.	Calculation of hydrocarbon degradation was based on the difference between the initial and final TCIC concentrations in the first lift and dividing that value by the amount of time required for treatment of soil in that cell in the first lift. The values shown represent the range measured for the eight treatment subplots.
PAH degraders (cfu/gm)	1.0x10 ⁵ - 5.0x10 ⁷ (Lift 1) 7.0x10 ² - 4.5x10 ⁶ (Lift 2) No values were determined for Lift 3.	"Replica Plating Method for Estimating Phenanthrene-Utilizing and Phenanthrene-Cometabolizing Microorganisms," Shiaris, M., Cooney, J., <i>Applied and Environmental Microbiology</i> , February 1983, Vol. 45, No. 2, pp. 706-710.
Total heterotrophs (cfu/gm)	7x10 ⁵ - 9.9x10 ⁷ (Lift 1) 6.3x10 ⁵ - 6.6x10 ⁷ (Lift 2) 7.0x10 ⁴ - 1.1x10 ⁷ (Lift 3)	"Agar-Plate Method for Total Microbial Count," F. Clark, <i>Methods of Soil Analysis</i> , Vol. 2, pp. 1460-1465.
NA - not applicable. Measurement procedures are reported only for those parameters where different procedures are available.		